NAPA VALLEY: CLIMATE ALERT HOW INVASIVE SPECIES GET HERE

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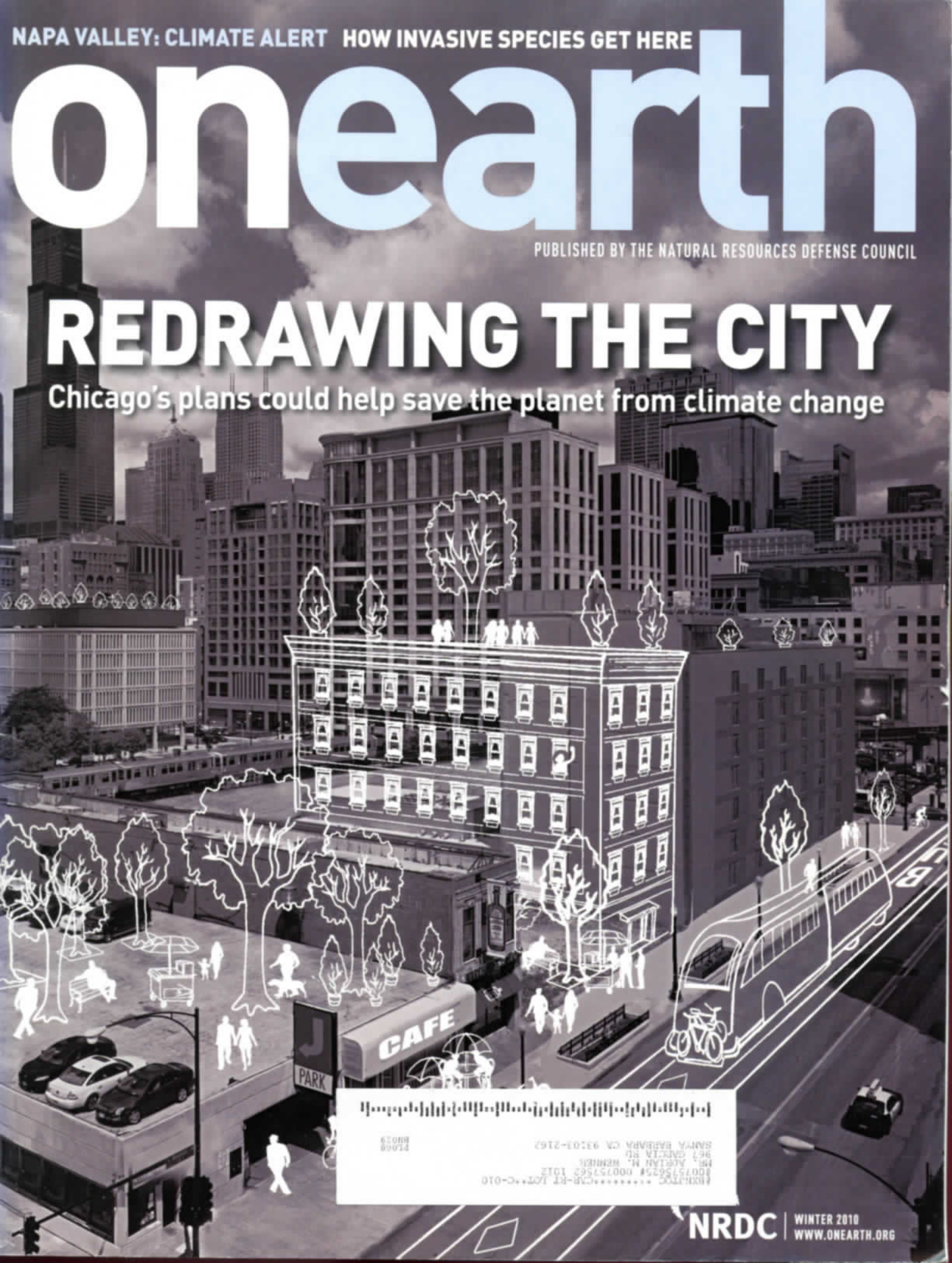

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PHOTOGRAPHS BY DAVID BUTOW

Riddle of the Shells

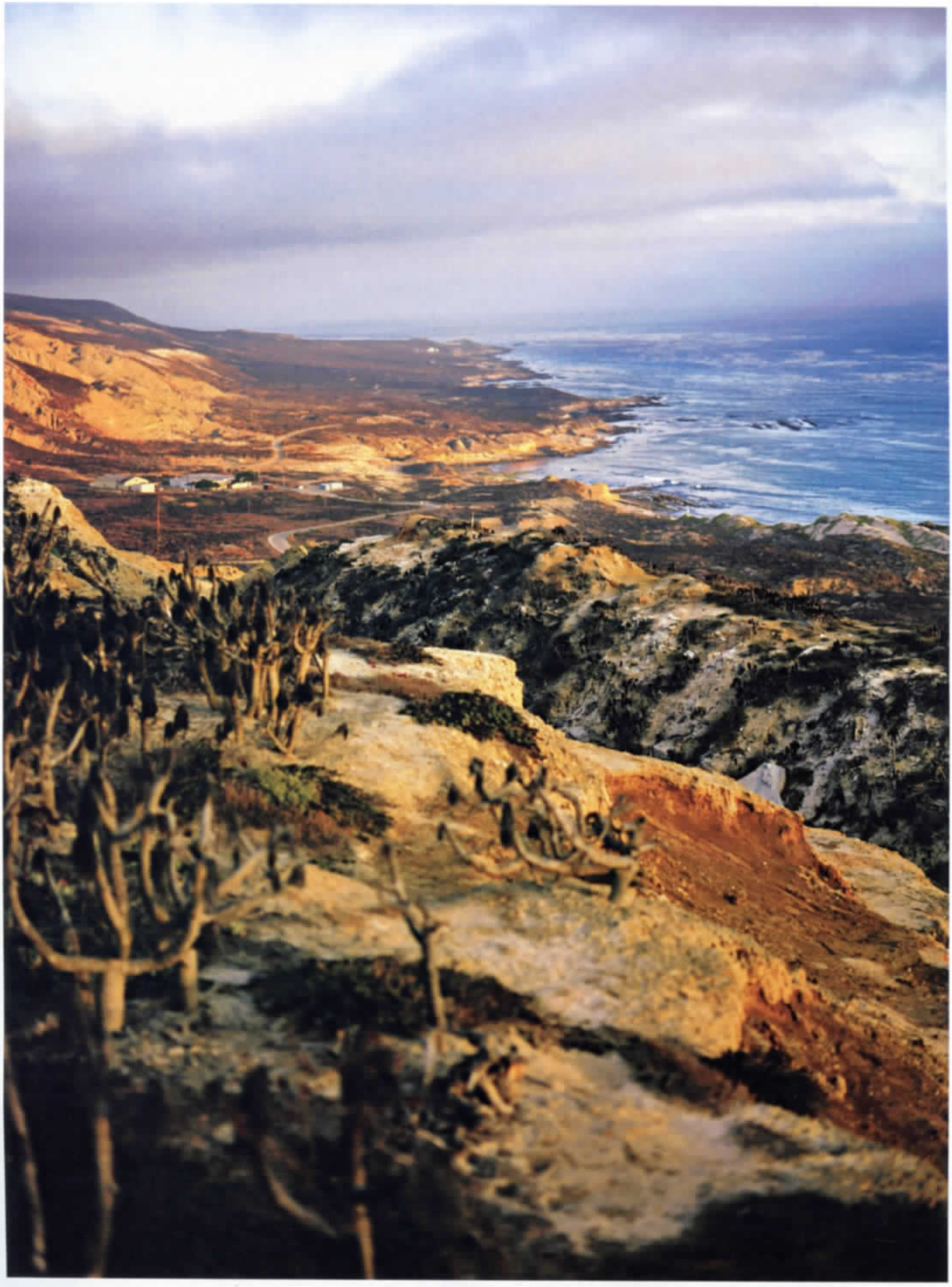
Once upon a time, our oceans teemed with life. But when exactly was that time? Archaeologists may have new clues.

AN ETERNAL WIND RIPS ACROSS SAN MIGUEL Island, scouring stretches of open sand and bending the blackened branches of shrubs. The most far-flung of a chain of islands that dot the Santa Barbara Channel off the coast of southern California, San Miguel has drawn fishermen ever since the earliest people settled North America. This stark landscape is surrounded by a thriving submarine jungle of kelp that is prime habitat for an array of fish, shellfish, and marine mammals. For millennia, it was the best place in southern California to collect abalone, the giant mollusk that once carpeted the seafloor of the Channel Islands. Now, after decades of over-harvesting, southern California abalone populations are badly depleted, echoing a global pattern in which the bountiful ocean morphs into a sea of ghosts.

During the past decade, scientists have come to understand the extent to which overfishing has emptied the oceans. In 2003 an influential study in the journal *Nature* concluded that many populations of large fish had plummeted to 10 percent of their 1950 levels. The research drew on coastal marine surveys and catch data from Japanese long-lining, an intensive industrial fishing method used in all the world's oceans except the circumpolar seas. The study showed that predators such as marlin and tuna are now caught when they are relatively small; many don't live long enough to reproduce. This grim trend is evident on coral reefs, in the deep waters of the open oceans, and in kelp forests off southern California.

The sluggish abalone may not be as charismatic as a free-roaming ocean giant like the tuna, but its plight encapsulates the human foibles that have led to dev-

BURIED TREASURE
Students and instructors from an archaeological field school at California State University, Los Angeles excavate a prehistoric village site on San Nicolas Island.



looks like. Researchers who surveyed abalone in the 1960s and 1970s reported densities several times higher than today's. Despite this, Voss insists, based on his own observations of the shellfish and his idiosyncratic interpretation of data from government biologists, that the population at San Miguel is "phenomenally robust." For him, the state of the abalone now, a mere dozen years after emergency closure of the fishery, is an adequate measure of a healthy population.

Different players rely on very different baselines to judge the health of the abalone: Davis has had his eye on the creatures for six decades, while Voss's perspective covers less than 20 years. Todd Braje, an energetic young archaeologist at Humboldt State University, takes a longer view; he believes it may be possible to glimpse ancient abalone populations that lived as much as 12,000 years ago. "If we're going to remedy the shifting baseline syndrome," he says, "we need to look as far back in time as we can."

The arid sands of the Channel Islands hold relics of some of the earliest human inhabitants of North America. The Chumash people, once one of the world's most populous hunter-gatherer societies, left their spear points behind in Daisy Cave, a narrow sandstone cleft at the northeastern edge of San Miguel. Eroding dunes reveal an abundance of prehistoric tools, including beautiful fishhooks formed from the shells of red abalone. These hooks could be used without bait: one side, coated in the pearlescent material that lines the interior of an abalone shell, would flash underwater, acting as a lure.

The islands also reveal the remnants of ancient feasts. Fragments of sea urchin test—the delicate domes that once encased the bodies of these tasty invertebrates—lie scattered like bits of broken porcelain. When sunlight breaks through the clouds it brings out the gleam of abalone shells, whose meat was a staple food for the Chumash.

Combing through Chumash middens on San Miguel and the neighboring islands of Santa Rosa and Santa Cruz, Braje has analyzed shifting patterns in the size and abundance of abalone shells. His work shows that the Chumash feasted steadily on abalone for thousands of years, both devouring and coexisting with the great snails. (Part of this, of course, had to do with technological limits: prehistoric people lacked scuba gear, and many abalones would have remained beyond reach, producing larvae that could repopulate shallow areas close to shore.) Braje has studied heaps of ancient, whopper-size red abalone shells that tumble out of sand dunes like a collection of calcified ladies' hats. Such finds are scattered across several of the islands, but San Miguel holds the densest concentrations of red abalone shells.

MAP BY MIKE HOGAN

SOUTHERN CALIFORNIA IS HOME TO SEVEN SPECIES of abalone, five of which have been commercially fished. Black abalones grow in the intertidal zone and are particularly vulnerable: they can be pried off the rocks by anyone willing to get wet feet. Reds and pinks live farther out, below the tide line. Together, these two species sustained the fishery for decades. Hopes for its renewal focus on the red abalone, the most resilient and widespread abalone species. Yet over much of its traditional range, populations are so depleted that the once ubiquitous creatures are hard to find. The white abalone, California's deepest-dwelling species, was once abundant off the Channel Islands, with as many as 10,000 per hectare (2.47 acres) in some stretches of rocky habitat. In the 1990s Davis supervised an intensive search for abalone using scuba divers and a manned submarine. Whites had become a rarity; he and his colleagues found fewer than two animals per hectare. The species is now listed as endangered.

To understand why high densities are vital to a population's long-term health takes some basic knowledge of abalone sex. A good-size female red abalone will pump out about four million eggs a year. But unless breeding adults live in high density on the seafloor, sperm and eggs become so dispersed that they're unlikely to connect. To achieve breeding success, abalones must generate enough larvae and juveniles to satiate all the fish and lobsters that will snap them up, with enough surviving to establish a new generation. Even where abalones are present in large numbers, they may produce viable numbers of offspring only once every four or five years.

Fishery biologists didn't realize until the 1990s that nature had programmed the abalone to play reproductive roulette. Earlier regulations had set minimum size limits for harvesting. "We were removing all the large animals, and that's where the reproductive capacity lies," Davis explains. The biggest abalones produce the most abundant spawn. They also bring the highest prices. (In the last year of the legal fishery, such animals sold for $500 a dozen. Today, sizable red abalones can sell for $100 each on the black market.) In a 30-year lifespan, an animal may get four or five chances to produce offspring that live long enough to carry on the breed.

In its Abalone Recovery and Management Plan, California's Department of Fish and Game (DFG) laid out the critical numbers to be used in assessing the health of abalone populations. The guidelines relied on studies of red abalone in northern California (where only a limited sport harvest is allowed and the use of scuba gear is forbidden) and other stable stocks scattered around the globe. Studies from California, Australia, and New Zealand show that abalones need to be in dense aggregations of

ANTIQUE TACKLE The Chumash fashioned fishhooks out of red abalone shell and used eelgrass as fishing line. Hook and line were glued together with asphaltum, a tarlike substance that seeps out of cracks along the coast of southern California.

6,000 to 8,000 per hectare to be sustainably fished. Once the density falls below 2,000 per hectare, reproduction essentially ceases. If the number plummets below 1,000, the abalone is unlikely to recover without active human intervention—for example, by moving large, mature animals closer together, a strategy that showed some promise during a 1980s experiment with pink abalone from Santa Barbara, one of the southern Channel Islands. A healthy population should also have a mix of large, medium, and small animals. If an area holds large abalones but no younger ones, that's a signal of reproductive failure.

During the past three years, surveys of unprecedented thoroughness have been conducted in the waters surrounding San Miguel. Former abalone fishermen put on their diving gear and worked together with DFG biologists to collect the data. They found that red abalones at San Miguel are scattered, occurring at densities ranging from 160 to 1,600 per hectare, well below the levels needed to make a population self-sustaining. Large, impressive animals dominate, but young ones are rare: according to Davis, they are found at less than a tenth of the numbers thought to show successful growth of new generations.

Recreational divers who visit San Miguel today see the red abalone as fabulously abundant. Yet a couple of decades ago, the population there was 10 times denser. "The comparison people make with the other places they've seen in their personal experience makes San Miguel look like it's still okay," Davis says. "That's true even for people who've been involved with abalone for a long time." The big animals that so impress divers at San Miguel today represent the last remnants of a once bountiful stock.

Braje's research suggests that the chilly, nutrient-laden waters around San Miguel have long held southern California's greatest bounty of abalone; because the area is so remote and so biologically rich, it was among the last to be affected by overfishing and retains more large abalones than any other place. The prehistoric evidence tells us to expect abundant abalone at San Miguel: recovery, when it comes, should be noticed there first.

Working with several colleagues, including Paul Dayton, a noted marine ecologist at the Scripps Institution of Oceanography, Braje co-authored a paper for the journal *Ecological Applications* that draws on an unconventional mix of ecology and archaeology. They compared patterns in the size and abundance of abalone shells in ancient middens on San Miguel, Santa Rosa, and Santa Cruz with catch records from the twentieth-century commercial fishery. The sites with the greatest abundance of ancient, outsize red abalone shells match up with the most productive locations for commercial fishers. San Miguel holds by far the greatest concentration.

Braje believes that the archaeological record can help fill critical gaps in our understanding. Many marine scientists remain skeptical about how much they can learn from ancient relics, and he is the first to admit that archaeology cannot meet the detailed standards demanded in modern biological surveys. But quantitative data often extend back only a few decades, while human interactions with ecosystems have been going on for millennia.

For Braje, seeing the retrospective study of the abalone catch in a peer-reviewed ecology journal was a rewarding breakthrough. His leap beyond the traditional boundaries of archaeology is part of a broader movement that looks to the deep past to understand and restore depleted fisheries. Important clues have come, for example, from the bones and scales of great cod and sturgeon, caught hundreds of years ago on the banks of the North Atlantic, and from eighteenth-century ships' logs, which record an unimaginable abundance of sea turtles in the Caribbean and whales in the Pacific.

Braje and his colleagues found that during the commercial fishing of the twentieth century, San Miguel's waters yielded more than twice as much abalone, by weight, as Santa Rosa's or Santa Cruz's. That relative abundance appears to have held for thousands of years, regardless of shifting ocean temperatures that affected populations elsewhere in the Channel Islands. Braje suspects that the cooler waters around San Miguel and off the southern coast of Santa Rosa represent critical abalone habitat. The animals growing in this area may help to keep populations stocked farther to the east.

The take-home lesson is that San Miguel should not be used as an indicator of population health in the rest of the Channel Islands. A truer test of an abalone rebound would be an increase in density, along with a rise in the number of younger animals, farther south and east along the island chain.

That makes sense to Davis. "San Miguel is clearly a source of replenishment for a much larger region," he says. "It's at the tail end of the cold water that comes down from the north in the California Current, so it's in the right position to serve that role."

Advocates on both sides of the debate see a lot riding on San Miguel. For commercial divers, it represents perhaps the only chance to fish for abalone again in their lifetimes. For conservationists, it is the last hope to restore the abalone's former abundance.

The abalone fishermen, Davis suggests, are like the buffalo hunters who clung to a cherished way of life after all the herds had been shot. "These guys would like to keep hunting and gathering," he says, "and I'd like to see the integrity of southern California coastal ecosystems rebuilt, so they can keep doing that." But this remains a distant goal. "We're down to the last little center of population," he says. "It's like the seed corn. Do we want to keep it, or sell it?"

Sharon Levy's book Once and Future Giants: The Fate of Megafauna in a Human World *will be published by Oxford University Press in 2010.*